The Institute of Physics

BULLETIN

JUNE 1958 · VOL. 9 . No. 6

CONTENTS

NOTICES TO MEMBERS
Page 133

FORTHCOMING INSTITUTE MEETINGS
Page 134

THE SPINNING GALAXY—
A HISTORY IN CO-OPERATION BETWEEN SCIENCES
MARTIN JOHNSON
Page 135

A SECOND SURVEY
OF AVAILABLE PLACES FOR PHYSICS STUDENTS IN UNIVERSITIES AND TECHNICAL COLLEGES
N. CLARKE and JEAN B. M. BOWERS
Page 143

NEWS OF MEMBERS
Page 148

BRANCH AND GROUP NEWS
Page 150

THE REGISTER
Page 153

THE INSTITUTE'S JOURNALS
Page 155

The Bulletin is published by The Institute of Physics for circulation to its members.

Notices to Members

The Institute's Finances

Details were given in the January *Bulletin* of the budget that had been approved by the Board for 1958, based upon recommendations of the Finance and General Purposes Committee made in November last. Since that budget was drawn up, it has become clear that various influences largely outside the control of the Board made it desirable to re-examine the budget in the light of additional information. This has been done and a new budget has been discussed by the Board. In common with other similar bodies the Institute has found that revenue from advertisements in journals has tended to fall in the last year and that the circulation of journals through retail channels has not increased as much as was hoped and expected. Although these may be temporary phenomena the Board now feels it prudent to reduce the estimated income from these sources. Since, at the same time, there have been inevitable increases in costs it is expected that there will be a deficit on the 1958 accounts of about £1,000 before allowing for writing off expenditure on alterations, providing for depreciation and allowing for the premium of the leasehold redemption policy. The final deficit is expected to be about the same as that of 1957.

Income Tax—Allowance of Subscriptions to Professional Bodies as Expenses

In his budget speech the Chancellor of the Exchequer announced that he proposed to allow certain professional subscriptions and fees to rank for tax relief under Schedule E. This would allow those in whole-time salaried appointments to charge such fees as expenses for tax purposes in the same way as those engaged in private practice have been allowed to do in the past. The necessary authority to permit the new concession is contained in section 14 of the Finance Bill, which is still before Parliament. Tax relief may be granted on " any annual subscription paid to a body of persons approved for the purposes of this section by the Commissioners of Inland Revenue";

various sub-sections of section 14 indicate the type of body likely to be approved by the Commissioners of Inland Revenue. The Board of the Institute will, of course, take such steps as are appropriate when the Finance Bill becomes law, so as to endeavour to secure that members of the Institute shall be able to claim tax relief on Institute subscriptions.

User-Specification for High-Temperature X-ray Diffraction Powder Cameras

The X-ray Analysis Group of the Institute announces that a panel of its Equipment Sub-Committee has completed the preparation of a user-specification dealing with the design of X-ray diffraction cameras for the examination of polycrystalline specimens at high temperatures. Copies of this specification may be had by any interested person on application to the Honorary Secretary of the Equipment Sub-Committee of the X-ray Analysis Group, Dr. E. G. Steward, Research Laboratories of The General Electric Co. Ltd., Wembley, Middlesex.

Australian Conference on Solid State Physics

The Australian Branch of the Institute has decided to hold a Conference on Solid State Physics in Melbourne in August, 1959. About 40 physicists from various parts of Australia have already indicated their intention to attend and to read papers on original work. It is hoped that some visitors from overseas will be present. Details may be obtained from the convenor of the organizing committee, Dr. W. Boas, C.S.I.R.O., Tribophysics Laboratory, University of Melbourne, Carlton, N.3, Victoria, Australia.

Applied Spectroscopy Group—Cancellation of Meeting

The Committee of the Applied Spectroscopy Group has decided to cancel the two-day meeting that was to have been held in Cambridge on June 19–20.

Forthcoming Institute Meetings

June 20 South Western Branch

Summer Meeting

Visit to the Norman Lockyer Observatory, Sidmouth

followed by

"Astronomical and Atomic Time"

DR. L. ESSEN

(*National Physical Laboratory*)

July 12 Education Group

Summer Meeting

Visit to Dulwich College

(Further details are available from the Institute)

Vol. 9, June, 1958

The Spinning Galaxy — A History in Co-operation between Sciences*

By MARTIN JOHNSON, M.A., D.Sc., F.Inst.P.
(*Reader in Astrophysics, University of Birmingham*)

1.

IT is sometimes said that astronomy in the middle of the twentieth century tends to lose its identity under a cloak of physics. There are two points at which such a statement may become an embarrassing partial truth. Firstly, any observatory is a very rigorous testing ground for modern physical techniques, especially for electronic methods in optics; for example, a d.c. amplifier may need to be stabilized in a photomultiplier circuit for tracing the fluctuations in an individual faint star, where gains of 10^{15} between primary and final currents are required as well as a precise following of that microscopic image. Secondly, an isolated hot sphere of 10^{33} or 10^{34} grams of gas, which men call a "star," must raise problems in thermodynamics of radiation, nuclear energy, optical electronic levels, and perhaps also in fluorescence of ejected gases, magneto-hydrodynamic turbulence, binary tides, and shock wave propagation. But to-day I do not propose to exploit these intriguing topics; I will suggest instead an even wider attraction which astronomy now offers to the physicist; I would particularly like to appeal to those interested in education in a wide cultural sense, concerned with the mark which physics can make in the mind of industrialist or schoolboy or young researcher. In accord with that educational interest, I shall spend the time telling a little about how rotation of the Galaxy has been discovered and has revealed definite problems in evolution, including for example large-scale magnetic fields and cosmic rays. For it might well prove instructive to see some of our simplest elementary principles of angular momentum applied to the system of a hundred thousand million stars in the Milky Way. We may in fact link the largest mechanism of Nature with the tricks which the beginner plays in his first laboratory. Sciences as far apart as photography, geometry, statistics, magnetics of ionized gases, spectra in radio wave bands, will serve the linkage.

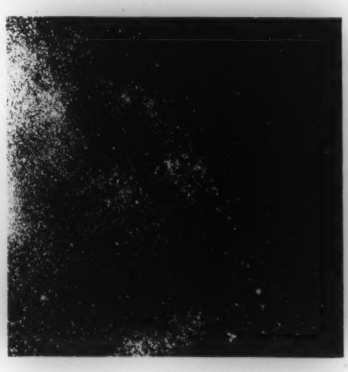

Fig. 1. *Milky Way in Cygnus (Barnard)*

On a clear moonless night, away from city lights, the sky is crossed by the broad band of dim light which since early times has been called the Galaxy or Milky Way. By what chain of investigations has it become possible to regard this assemblage of "particles," each comparable with our sun, as the largest spinning unit in Natural History accessible to us, containing 10^{11} stars with a rotational period of 2×10^8 years?

2.

The tale begins early in the eighteenth century, when geometrical positioning of "fixed" stars became sufficiently accurate for their minute individual shifts to be noticed; the first problem was to free these shifts from the large daily and annual effects of rotation and circulation of the earth, and the earth's slight precessional creep.

*Based on a lecture to the Education Group of the Institute on March 5, 1958

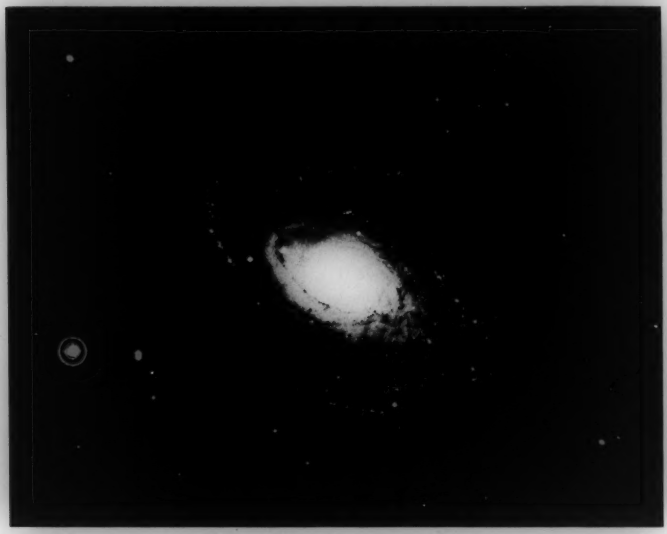

Fig. 2. *Spiral M81 in Ursa Major (Palomar).*

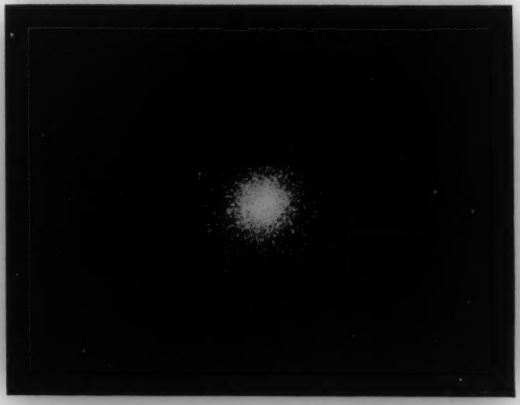

Fig. 3. *Cluster M13 in Hercules (Palomar).*

Later, in the nineteenth century, such observations of motions transverse to the line of sight were supplemented by the Doppler displacements in star spectra giving the component of motion along the line of sight: it seems an accident that the term " proper motion " is conventionally attached only to the transverse component, but " radial motion " obviously is suitable for denoting the inference from shifts in spectral lines. Halley, only the second of the Astronomers Royal, in 1718 detected proper motion in a few stars by comparing contemporary micrometric positions with early star catalogues; it appeared that Arcturus had moved by one degree and Sirius by half a degree during the many centuries since Ptolemy. Before the end of the eighteenth century the elder Herschel had found enough of such proper motions to make a first provisional extraction of the sun's own drift towards the constellation Hercules, the drift which must be a constant factor to complicate the apparent displacements of the stars. By the middle of the nineteenth century Bessel, and also the Struve who was ancestor of the present great Californian astronomer, were obtaining annual displacements of near stars due to parallax, thus making possible a first attempt to estimate steller distances. Before the end of that century Huggins, Vogel and others were obtaining the first radial velocities from micrometric study of displaced spectral lines. Once transverse proper motions and also this spectroscopic motion along the line of sight were both accessible, the plotting of actual movement in speed and direction became in principle feasible ; but we shall notice below that conditions favourable to the one kind of measurement are against the other.

The science so far is that of optical micrometry, the comparing of stars in an eyepiece or on a photographic plate and the calibrating of very small displacements of spectral lines on a plate. It will be worth pausing, briefly, to look at the orders of magnitude of some of these purely geometrical and kinematical quantities, both the quantities which we seek and those which we must eliminate to clarify the search. Apart from the daily apparent sky rotation and the visually obvious annual shift of the star map relative to the sun, due respectively to the earth's spin and orbit, and the 26,000 year precession due to the earth's gyrostatic behaviour, we must also eliminate for the study of real stellar motions the effects of parallax and aberration, although parallax itself is a clue to distance and thus an essential feature in judging motions. Both parallax and aberration each provide a tiny annual elliptic shift of star images ; aberration denotes the compounding of the earth's orbital velocity with the velocity of light and is independent of distance, tracing its little circle of 20″·47 at the pole of our orbit and tracing a corresponding length of line in the plane of our orbit with ellipses at intermediate angles. Parallax, with similar but smaller ellipses and linear tracks, does vary with stellar distance, reaching only 0″·76 for even the nearest star; it denotes the annual shift in apparent direction of a star as we move across a base line made by our radial distance from the sun. As a means of determining stellar distances it is practicable for about 6,000 near stars whose parallax exceeds 0″·005. A statistical or " mean parallax " extends this limit valuably, using as base line not our periodic orbit but the progressive drift of the whole solar system including ourselves.

Superposed on these apparent displacements of stars caused by the orbit of the earth around the sun, we next have to extract the stellar drifts obtained from the proper motions and radial motions, the two observed components which we have already classified as data for founding a galactic physics. By superposing plates taken years apart, proper motions have been assigned to over 50,000 stars ; there are useful techniques, such as mechanical or optical oscillating of the two plates so that any stars which have moved appreciably can be picked out by the " blink " effect. As a case illustrating the orders of magnitude, at a distance of thirteen Light Years a star with the quite reasonable proper motion of 20 km per sec. will shift by as much as one second of arc in a year. Plate measurements can be made to 0″·01, and for rough comparison we may recollect that the size of the moon's image is about 2×10^5 times that limit. Radial velocities are again a matter of micrometry of plates, in this case spectrograms: Bok's great book on the Milky Way suggests vividly to the experimental physicist the nature of the problem, by exhibiting a plate of the faint interstellar lines D_1 D_2, six angstroms apart but separated on the picture by about a centimetre. Two distinct components of each " monochromatic " frequency are about two millimetres apart, implying line-of-sight velocities of 55 and 7 km per sec. in two separate sodium clouds thus revealing their presence between us and the star. But this illustration utilizes the very high dispersion available with the light-gathering power of the unique two-hundred inch reflector at Palomar.

Radial oscillation of lines due to binary star pairs, and other complications such as gases

erupting between the pairs, must of course be taken into account in assessing the velocity of a single star or of the mass-centre of a pair. In spite of these difficulties there are now catalogues containing as many as 15,000 stellar radial velocities.

3.

But when these tens of thousands of stellar velocities, in transverse or in radial components, have been assembled, what fraction of any velocity is " real " and what is due to the motion of the sun itself with ourselves closely attached in the solar system ?

Fig. 4 illustrates this problem: suppose first that the stars are all stationary, except our sun which has a drift from right to left. After eliminating parallax and aberration, we and the earth can be identified hereafter with the sun as an observing point. Stars near the " apex " A_1 towards which the sun is drifting (actually at about 19 km per sec.), and stars around the antapex A_2 180 degrees away across the sky, will appear to have maximum radial terms of approach and recession respectively ; whereas stars in directions perpendicular to A_1 A_2 will show no radial component but the maximum transverse or " proper " motion, e.g. at P. The net consequence on the sky will be that the pattern of stars ahead of us will seem to be progressively " opening out " and behind us " closing in," by reason of the sun's motion alone.

The next step is to add to such effects of the solar motion any consequences of the fact that the stars themselves are not stationary: until the twentieth century it was assumed that this would merely superpose a random set of velocities upon the spurious shifts enforced by the sun's drift. Suggestions were made of applying the equations of gas-kinetics to an assemblage where each molecule is a star.

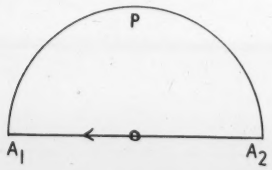

Fig. 4. *Effect of solar drift on apparent motions in stationary star system : radial velocities at apex A_2 and antapex A_1 but proper motions at P*

4.

To represent the combination of these star drifts with the solar drift, and enable statistical work on the problem to begin, let us adopt the device of polar diagrams (Fig. 5) ; in such a graph a radius vector in any direction is proportional in length to the number of stars moving in that direction.

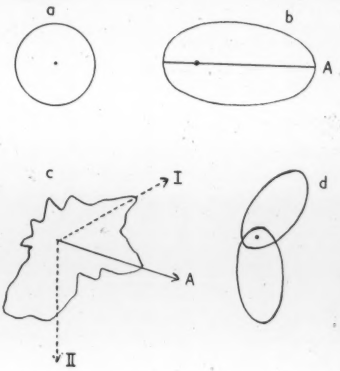

Fig. 5. *Polar diagrams : A, solar antapex ; I, II, star streams.*

A random distribution of stellar velocities would give a circular diagram, as in Fig. 5(*a*), becoming elongated in Fig. 5(*b*) if a solar drift from right to left is superposed. But diagrams constructed from the many thousand motions measured according to the principles which we have described yield irregular figures, as in Fig. 5(*c*) from Smart's work. Scattered irregularity is of course expected because of the groups with common or simple divergent or convergent motion which we call clusters; but in the polar diagrams which actually emerge empirically for selected areas of sky there are peaks or lobes not only representing the solar antapex but also implying two main predominating directions, instead of a single one. Fig. 5(*d*) shows how a smoothed model can be constructed to make up this double peak by combining two of the simple figures.

It was in 1904 that Kapteyn in Holland announced from such studies that stellar motions are neither random or singly preferential but

group themselves about two streams. Thereafter Eddington in this country and Schwarzschild in Europe (father of a present leading astronomer in U.S.A.), and in later years Chandrasekhar and Vyssotsky in U.S.A., Smart of Glasgow, Camm of Manchester, Kukarkin and Parenago in Russia, have developed analysis to show what underlies these bi-lobed diagrams by which the observed facts can be represented.

5.

Lindblad in Sweden seems to have been the first to suggest that the phenomenon of these directional star streams is a natural consequence of continuous rotation of the whole Galaxy, and the most vivid demonstration of this rotation in its accord with the simple laws of conservation of angular momentum has been due in the last thirty years to Jan Oort and his colleagues at Leiden in Holland.

Before realizing the significance of Oort's diagrams, it is necessary to look back at evidence accumulated before and during the First War as to actual distances across the Galaxy, and as to our own location therein. Systematic countings of stars in selected areas of sky along and across the galactic plane, plotted respectively in longitudes around and latitudes perpendicular to that plane, had already revealed that the shape of this universe of stars is a flattened disc. For instance there is the fundamental work of Seares and Van Rhijn; their comparison of counts by latitude according to stellar brightness, which is primarily according to nearness, exhibits the flattening since the more distant depart the more radically from spherical distribution and reveal the crowding towards the galactic plane. Counts by galactic longitude then arouse the suspicion that we ourselves are nowhere near the centre—the final downfall of human conceit as to favoured location in the universe, a conceit already shaken by abandonment of geocentric models of the solar system some centuries earlier. If it could be inspected from a distance great even relative to its size, the galaxy would resemble the well-known Andromeda "nebula" which is now recognized as another galaxy, one of many and actually the nearest to our own and probably containing a somewhat similar hundred thousand million stars. At this point we also recollect that the shape of a flattened disc does suggest rotation.

But the most decisive step in mapping our situation within the galactic shape came from Shapley's classical study, 1916-19, of the distances and distribution of the Globular Clusters. There are about a hundred of these clusters associated with our galaxy, but they are not tied to the flattened disc so much as scattered across it like a spherical "exoskeleton" concentric with the disc. Each of these Globular Clusters contains about 50,000 to 100,000 stars, and Shapley obtained their enormous distances by skilful use of pulsating stars of high intrinsic luminosity but faint by their remoteness: for it is one of the most convenient empirical facts in stellar physics that certain types of pulsating stars show a relation between mean intrinsic luminosity over the pulsation cycle and the periodic time of that cycle. Intrinsic luminosity and hence distance is therefore obtainable even if too far for observable parallax. Shapley's work revealed not only the vast scale of the galaxy, but also that our sun is situated slightly off the central galactic plane but at a much greater distance from the central axis.

It is useful at this stage to introduce units of distance: the Light Year has the obvious meaning of a distance such that light at a speed of 3×10^5 km per sec. takes a year to travel it, while the "parsec" is a distance such that the parallactic shift in position of a star by our annual traverse across the base line constituted by the radius of our orbit round the sun would amount to one second of arc. Recollecting that the nearest star has a parallax of 0".76, therefore a distance somewhat exceeding one parsec which itself would have been 3×10^{13} km, and that most seen stars are within a few hundred parsecs, the size of the galaxy can be stated as reaching a diametral spread of more than 25,000 parsecs in the plane of its disc but only about a tenth of this across the plane. We ourselves are then at about 8,000 parsecs or 27,000 Light Years from the galactic centre.

The important argument due to Oort, which has made the galactic spin so homely to elementary physics, can now be reproduced in Fig. 6. The diagram omits any ellipticity and simplifies the whole situation to a set of concentric circles of sample stars partaking of the rotation of the vast disc, some nearer to the centre than ourselves and some further out. In the Figure we are at the centre of the small set of circles, and the large circles are orbits around the galactic centre. As shown by the arrows in the left-hand picture, if the spinning galaxy behaves not as a rigid wheel but as a fluid around a massive centre in accord with the laws of distribution of angular momentum, those stars in their circular orbits further out radially than ourselves will rotate more slowly

than ourselves, and those nearer the centre will rotate faster. The former will lag behind our galactic circulation, the latter will get ahead of us. Enlarging this feature in the right-hand portion of Fig. 6, we notice that the phenomenon will ensure that stars seen in directions from us along a radius or a circumference of an orbit will show us zero approach or recession velocity, but velocities of approach and recession will appear and reach maxima along the diagonally orientated directions.

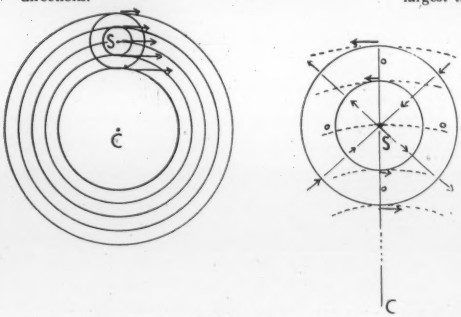

Fig. 6. *Differential rotation of Galaxy, giving zeros of radial velocity. S, sun ; C, Galactic centre.*

The proof of Oort's discovery that our Galaxy spins according to the familiar " inner faster, outer slower " law of angular momentum, taught in our elementary laboratories, appears in the plots of radial velocity against galactic longitude obtained by Joy at Mount Wilson. These graphs do show four zeros in the periodic range of velocity when abscissae are the orientations of our view around the galaxy, and furthermore the amplitude of the " wave " does become larger the more distant the stars chosen, as would be expected from diagrams of the kind shown in Fig. 6.

Of course actual graphs are very scattered: different types of star have velocities characteristic of their sort, or even individual to each star, and this first stage of Oort's great discovery concerns only the smoothed-out underlying pattern which is thus verified. The detection of peculiar velocities, runaway stars which exceed the galactic escape velocity, groups with common directional trend across the main track, etc., all offer clues to age and evolution which can serve a second stage once the basic structure of the spinning galaxy has been thus established.

6.

The most striking of those departures from the first hydrodynamic disc of Oort is the likelihood of spiral arms in the Galaxy, a source of maxima and minima of stellar concentration at certain radial distances. These arms might well be expected, as soon as it became clear that our own galaxy is a " universe " comparable with the many " external " galaxies such as the Andromeda nebula and all the others only revealed by the largest telescopes: for that structure of a double armed spiral is very obvious at sufficient distance. But is it possible to detect it as a character of our own galaxy, when we can only observe from a point inside ?

Relevant data in optical astronomy came in 1951 from Morgan, Sharpless and Osterbrock, investigating the distribution of Hα emission in the galaxy. But perhaps the most striking appeal to physicists and radio engineers will come from the work of Van de Hulst, Muller, and Oort just after the Second War. The difficulty of tracing our spiral arms optically is the amount of obscuration by cloud or dust or scattered microcrystalline material in distant parts of the galaxy ; but some bands in the radio emission spectrum of the sky are more penetrating than any optical wavelengths. Those Leiden astronomers predicted in 1944 that the stray interstellar hydrogen when neutral and atomic might exhibit a monochromatic radiation at 1420 Mc/s or 21 cm wavelength, by transition between parallel and antiparallel spins of proton and electron ; this involves an extremely small energy difference, far outside optical range and forbiddingly faint unless seen through depths of hundreds of parsecs. But those hydrogen clouds might well mark out concentrations of material more definitely than star counts. Americans, Australians, and the Dutch originators of this very fruitful idea, were able by 1951 to verify the prediction; the outlining of the galactic structure, in this 21 cm radio emission from gas accompanying stellar distribution, has not only confirmed the Shapley location of ourselves at about 8,000 parsecs off-centre, but has shown up patches of spiral arm structure far more unambiguously than possible to optical astronomy.

Fig. 7, reproduced by permission of Professor Van de Hulst, shows how the Doppler effect introduces components into the 21 cm line as the direction of reception is swung around the entire

circle of Galactic longitudes, the radial component of motion breaking into separate displacements as regions of high and low density associated with spiral arms and differential rotational speeds are traversed. The periodic passage across zero velocity also confirms a similar feature to that of Oort's optical problem in Fig. 6.

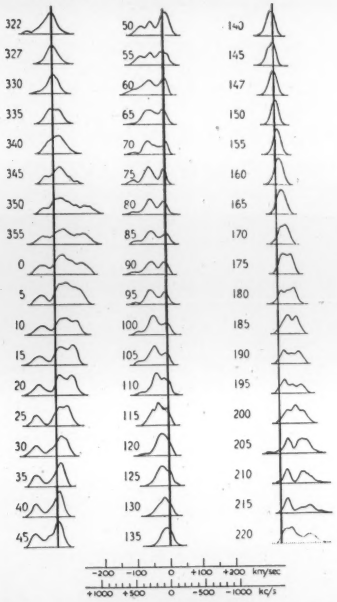

Fig. 7. *Structure of 21 cm radio line around Galaxy. (Van de Hulst, Muller, Oort.)*

Fig. 8 is a composite sketch from the 21 cm radio survey of the Galaxy, including results from Leiden and also from the great centre of radio astronomy at Sydney in Australia. Even so fragmentary a revelation that there is structure in the vast system which we discussed first as a disc, has set to-day's and to-morrow's problems of galactic physics. The change in emphasis extends the list of sciences from which we must draw theories and techniques: some can now be mentioned briefly.

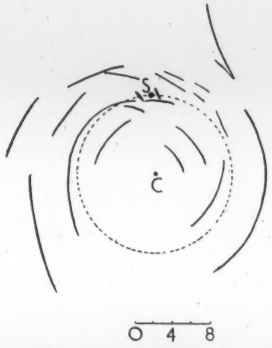

Fig. 8. *21 cm radio mapping of Galactic arms (Leiden and Sydney). Linear scale in kiloparsecs.*

7.

Photographic study of proper motions and spectroscopy of radial motion had prepared us for our own orbit around the galaxy, pursued at about 220 km per sec., and with the distances revealed by Shapley's employment of pulsating stars in Globular Clusters a period of rotation of about 2×10^8 years seems likely. This period is probably only a few per cent of the lifetime of the 10^{11} stars which partake of this rotation. But if such lifetime is to mean anything to a future physics of stellar evolution, there must be found some dynamic or hydrodynamic status for the spiral structure which seems to characterize our own Galaxy as well as external " universes " : The suspicion that electrodynamics or magneto-hydrodynamics will have to be taken into account at once forces the galactic astronomer to enter branches of science which the heroic collectors of velocity statistics had no time to consider.

One fertile suggestion at present being discussed is the possibility that, since large celestial bodies are now commonly found to have a definite magnetic field associated with their structure, the entire Galaxy may have a resultant field. But it is even more likely that the drifting interstellar clouds carry such fields. A pointer to widespread magnetic fields in space is the recent development in studies of polarization in distant star-light, by Hiltner, Lyman Spitzer, Davis, Greenstein, and others. Galactic or interstellar magnetic fields might solve the mystery of stabilizing those vast spiral arms, and progress towards

this has been made by Chandrasekhar the greatest of Indian theoreticians now at Yerkes Observatory in U.S.A.

Interstellar magnetic fields carried by the drift of ionized gas were also invoked in one of the most promising theories which have been proposed, that of Fermi, with the magneto-hydrodynamics of Alfvèn of Stockholm, to account for the acceleration of stray particles to an energy of 10^{11} to 10^{16} electron volts; it is well known that such energies have sometimes to be ascribed to cosmic ray primaries entering the earth's atmosphere from unknown sources. It is true that solar eruptions may account for transient bursts of the slower cosmic rays, of between 10^8 and 10^{10} electron volts, and many less " tame " stars than our sun may emit some of the more energetic, particularly during a super-nova explosion; but there is considerable leaning to the possibility that in the interstellar matter at extreme rarefaction there may occur collision of clouds, and the interpenetration of the fields may have violent enough effect on any ions present. Since neutral clouds were the source of the radio emission which traces the structure of the Galaxy and its spiral arms, the co-operation between sciences in elucidating the spinning galaxy has in the present decade spread over radio technology, the cosmic rays of nuclear physics, and electromagnetic theory on the vastest scale. It seems a queer atavism that the nuclear transformations of cosmic rays, galactic or other in origin, are now studied by the photographic plate whose first invention was a starting point of galactic astronomy a century ago.

No one can study the Galaxy, in any of the aspects upon which we have here touched, without an attraction to the problem of its age and the evolution of its individual stars; such discussion begins from the distinction between what Baade called Population One and Population Two, in " arm," " centre " or " fringe " or other portion fast or slow of a galaxy. Preliminary attempts have been made to associate these classifications with youth and age of a star according to the degree of nuclear transformation of its hydrogen into helium. This topic, sounding nearer to the atomic physicist than to the traditional astronomer, actually meets the seemingly kinematic problem of individual stellar velocities in their galactic orbits, since it is now recognized that the more elongated and highly inclined paths around the galaxy may denote membership of an age group. Degradation of a galactic orbit is in principle the same situation as with the trivial bodies of a mere solar system, but with far wider implications over the whole of physics including nuclear studies. Papers now being published at the Royal Astronomical Society by the present Astronomer Royal, and Dr. Eggen of Lick Observatory in U.S.A., Mount Stromlo in Australia, and latterly of Greenwich, represent well this joining of the older kinematic problem of the galaxy with the atomic implication of the evolutionary question to which it must ultimately give rise. Perhaps the most urgent problem of to-day is that " inner faster, outer slower " in the galactic rotation has challenging gradations in the latest Leiden Doppler profiles : is turbulence in the centre converted to magnetic energy in the spiral, or through shock waves to Cosmic Rays ?

A note on the literature of the subject may be of service to physicists who care to pursue the questions raised, by mentioning especially sources to which this lecture is indebted. The best account for general scientific readers is *The Milky Way* by B. and P. Bok (Third ed. 1957). A very lucid introduction to the study of stellar motions is scattered in several chapters of *General Astronomy* by Sir Harold Spencer Jones. Advanced study will require the large treatises on stellar dynamics and statistics by W. M. Smart in England, by Chandrasekhar in U.S.A., by Trumpler and Weaver in U.S.A., and by Kukarkin in Russia. A valuable survey of the evolutionary problems of the Galaxy is by C. Payne-Gaposchkin, *Variable stars and Galactic structure*. The pioneer work of Eddington is found in his early book, *Stellar movements*, and Shapley's brilliant use of Clusters can be read in his *Galaxies*. The recent work of Oort, Van de Hulst, Muller, and the Sydney radio astronomers is mainly in Dutch, English and American astronomical and astrophysical journals and the Australian technical papers. The Halley Lecture at Oxford in 1953 by Van de Hulst is especially to be recommended. The foundations of the application of electrodynamics to astronomical gases were laid by Alfvèn in *Cosmical Electrodynamics* (1950) ; the subject is controversial, and the most critical account is the recent monograph by T. G. Cowling of Leeds.

Vol. 9, June, 1958

A Second Survey of Available Places for Physics Students in Universities and Technical Colleges

(This report by Mr. N. Clarke and Miss Jean Bowers is published with the approval and authority of the Board of The Institute of Physics)

A REPORT on an inquiry into the availability of places for students of physics in British universities and technical colleges was published in the *Bulletin* in September, 1955. The principal conclusions drawn from the data then obtained were :

(*a*) that by no means all the available university places in physics were then filled—perhaps 20 per cent remaining vacant.

(*b*) that the proportion of those accepted who did not complete the Honours course was probably of the order of one-third.

(*c*) that the number of full-time degree students in technical colleges was rapidly declining and

(*d*) that the principal work of many technical colleges appeared to be of the type normally regarded as more appropriate to a university or to a grammar school. Most colleges had either not experienced or had failed to respond to any demand for courses in the more technical aspects of physics.

A second survey has now been conducted so as to obtain data relating to changes that have occurred since the 1954-55 session ; the information obtained is given in this report. The two sets of data are not always strictly comparable, partly because the second inquiry is based upon returns from more universities and technical colleges than the first and partly because significant changes in the structure of technical education have taken place since 1954 ; these are beginning to be reflected in the type of work undertaken by the larger colleges, especially those recently designated Colleges of Advanced Technology. Nevertheless, some interesting comparisons can be made.

A letter of inquiry was sent to thirty-five university departments of physics asking for the number of students admitted to the Honours school of physics in 1955, 1956 and 1957, the number of those students who had so far failed to complete the course and the maximum number of students that could be admitted if sufficient applications were received from students of adequate quality. Seventy technical colleges recognized by the Institute for the purpose of its membership regulations or recognized only for courses for the Ordinary National Certificate in Applied Physics were asked to supply detailed information about their staffs and their various courses. Replies were received from thirty-three of the thirty-five university departments and from sixty-nine of the seventy technical colleges. The universities and colleges that have supplied data are listed in Appendices I and II respectively.

RETURNS FROM UNIVERSITIES

The data refer exclusively to students reading for the Honours degree in physics or a comparable degree such as the Scottish degree in Mathematics and Natural Philosophy. In a few universities students intending to take the Honours degree may be required or encouraged to take first the course for a Pass degree or a General degree, but for such universities the figures given in this report refer only to those candidates who have successfully completed this earlier course and have entered the Honours course. Similarly, for the University of Cambridge, as the Institute recognizes Part II of the Natural Sciences Tripos as the equivalent of the Honours or Special degree of other universities, only candidates in the Part II course are included.

In the earlier report it was stated that about 750 students were admitted annually to the courses for the Honours degree in physics in the universities for which information was then available. As there were then six university departments that had not replied to the inquiry it would be reasonable to assume that the total number of admissions in 1954/55 was about 850. That total did not appear to have varied by more than about 10 per cent in any of the years since 1949. Another of the conclusions of the 1955 report was

that the number of additional students that could have been accepted into the university departments supplying information was about 170. Allowing for some vacancies in the departments for which no information was available, it would seem that the total number of places in all the British universities in 1954/55 for physics students was about 1,050.

The following are the numbers of students actually admitted to the Honours schools in the years stated in the thirty-three university departments supplying information :

Table 1.

Year		*Students admitted*
1955	...	979
1956	...	1,108
1957	...	1,314

It appears, therefore, that the intake in 1957 was some 25 per cent greater than the maximum number of students the universities were prepared to take three years ago. A few departments have substantially increased their capacities, although it may well be that some serious problems of accommodation now exist. The total number of places now available can be given only approximately, but it is probably somewhat less than 1,400. In England, apart from Birkbeck College —which is a unique institution with quite special entry requirements—university places seem to be fully taken, and the small number of possible vacancies, which, it should be added, might be realizable only at the cost of much inconvenience to the universities concerned, are almost all in Scotland and Northern Ireland.

None of the students included in Table I have yet reached the stage of the final examination and no firm figure can be given for the rate of failure. In general, the returns suggest that the rate of failure in the first and second years of courses is substantially below the estimated 30 per cent overall failure of 1955. Over the country as a whole about 15 per cent fail in the first two years, although any estimate can be only approximate. There is considerable variation between university departments ; in some the failure rate is 25 per cent, 30 per cent or even as much as 40 per cent. It should, of course, be borne in mind that " failure " here means failure to complete the Honours course ; most of these students continue at the university and satisfactorily complete other courses such as those for General or Ordinary degrees.

There has probably been some improvement in the general quality of the applicants for admission to the Honours schools, although more than one professor remarks that there has been no proportionate increase in the number of first-class people. The larger departments are able to select from very large and still increasing numbers of applicants. For example, the Head of a department (neither Oxford nor Cambridge) which admits about 35 Honours students a year writes, " Over 500 students apply for admission to this course, of which about 50 are selected for interview. Those accepted all have at least one distinction at ' A ' level and more than half are State Scholars." It is significant that with this wide choice, out of 36 students accepted in 1955, so far 5 have not been allowed to continue the course, although only 1 from 33 admitted in 1956 has yet been rejected.

It would seem that there is now real competition to secure admission to Honours schools of physics.

Some professors have suggested that an increasing number of applicants should be encouraged to enter courses for Ordinary degrees.

TECHNICAL COLLEGES

In each of the two surveys, information has been sought only from the technical colleges recognized by the Institute, either for courses leading to qualifications satisfying the Institute's academic requirements for membership or for courses leading only to the Ordinary National Certificate in Applied Physics. The fact that in three years the number of these colleges has increased by 25 per cent is some indication of the increased demand for technical courses in physics. A comparison of Appendix II of this report with the corresponding Appendix of the earlier report will show the no less significant fact that many of the colleges recognized in the intervening three years are situated away from the main centres of industry and are not colleges where it might have been expected that courses in physics would have been in much demand. Several of these colleges, however, have thriving courses for National Certificates.

Full-time Physics Staff

Table 2 gives the details of the physicists on the full-time staffs of colleges. In this, as in the other tables referring to technical colleges, the institutions have been placed in three groups : the recently designated Colleges of Advanced Technology (eight in number) ; the London colleges not so designated (Borough Polytechnic, Northern Polytechnic, The Polytechnic Regent Street, Sir John Cass College, South-East London Technical College, West Ham College of Technology, Woolwich Polytechnic and the Brunel College of Technology, with which the Acton

Table 2.—*Grading of Full-Time Physics Staff.*

	Head of Dept.	*Senior Lect. or Reader*	*Lecturer*	*Assistant Grade B*	*Assistant Grade A*	*Total*
Colleges of Advanced Tech. (8)	7	29	35	18	—	89
London Tech. Colleges (8)	6	22	33	27	—	88
Other Colleges (53)	35	32	104	111	11	293
All Colleges (69)	48	83	172	156	11	470

Table 3.—*Full-time Staff comparison : First Survey (end of 1954) and Second Survey (end of 1957)*

	Head of Dept.	*Senior Lect.*	*Lecturer*	*Assistant Grade B*	*Assistant Grade A*	*Total*
53 Colleges						
First survey	41	50	106	116	29	342
Second survey	40	71	142	131	4	387

(*Note : Data refer only to the 53 colleges supplying information for both surveys.*)

Technical College has so far been retained) ; and the remaining fifty-three colleges which in general would be of smaller size than colleges in the first two groups.

Physics is taught in variously designated departments. In the largest colleges which have strong physics sides the subject is usually taught in a separate department of physics, although there are still some colleges with very strong courses in physics where responsibility for the subject is borne by Departments of Mathematics and Physics, Engineering or Applied Science. In the smaller institutions it is common to have only a Science Department. As will be seen from Table 2, there are only forty-eight of the sixty-nine colleges where a physicist is Head of the Department in which physics is taught. It is perhaps surprising to find that among the sixteen Colleges of Advanced Technology and London technical colleges there are three departments where physics is the ultimate responsibility of someone not a physicist. Two of the Heads of Department concerned are engineers and the third is a chemist.

Table 3 gives a comparison of the staffing position now and three years ago in those colleges which have supplied information for both surveys.

The number of physicists on the staffs of these colleges has increased by 47 (or 13 per cent) in three years and at the same time the general seniority of grading has significantly improved. Excluding the Heads of Departments, the proportion of staff graded as Senior Lecturer or Lecturer has improved from 52 per cent to 61 per cent.

Degree Candidates

The number of candidates presented for London degrees, either the Special physics degree or the General degree with physics as one of the three subjects, has continued to decrease although the decrease in the part-time General degree work has been comparatively small. Details are given in Tables 4 and 5

Table 4.—*Candidates for Special Physics degree*

	1955		*1956*		*1957*		*No. of Colleges*		
	Full-time	*Part-time*	*Full-time*	*Part-time*	*Full-time*	*Part-time*	*1955*	*1956*	*1957*
C.A.T. (8)	15	13	9	6	10	2	5	4	3
London (5)	36	22	27	26	18	11	7	7	6
Other Colleges (53)	15	14	7	12	3	1	9	7	3
Total	66	49	43	44	31	14	21	18	12

Table 5.—*Candidates for General Physics degree*

	1955		*1956*		*1957*		*No. of Colleges*		
	Full-time	*Part-time*	*Full-time*	*Part-time*	*Full-time*	*Part-time*	*1955*	*1956*	*1957*
C.A.T. (8)	23	92	15	84	10	67	6	5	6
London (8)	26	119	18	110	16	95	7	7	7
Other Colleges (53)	72	158	57	156	50	159	37	39	35
Total	121	369	90	350	76	321	50	51	48

It will be seen that in 1957 twelve of the sixty-nine colleges presented a total of 31 full-time and 14 part-time students for the Special physics degree. Of the three Colleges of Advanced Technology offering candidates, one (Battersea College of Technology) presented eight full-time students, one college presented one full-time and two part-time candidates and the third presented one full-time student. Of the other London colleges, three each offered four full-time candidates, one three and one two. The remaining candidates were from three colleges in the third group. One college presented two full-time, another one full-time and a third one part-time candidate. No information is available upon the success of the candidates. It seems reasonable to draw the conclusion that, if special classes or tuition were provided for these candidates the cost was highly uneconomic while, if the tuition were not provided it is doubtful whether the candidates should have been presented.

The figures for General degree students are larger although many of the classes must still be very small. It is interesting to note that the sixteen larger colleges (Colleges of Advanced Technology and other London institutions) have been reducing their work for the General degree (26 full-time and 162 part-time in 1957 against 49 full-time and 211 part-time in 1955) while the other (in general much smaller) institutions have maintained their part-time work at a steady level and have reduced their full-time numbers by a lesser amount.

Non-degree work

There has been a welcome increase in the volume of work in physics for courses other than those leading to the degrees of the University of London. Table 6 gives the numbers of candidates in the final years for the Ordinary and Higher National Certificates in Applied Physics for each of the last three years, and it will be seen that in two years the candidates at the Ordinary level have increased by 50 per cent and at the Higher level by 60 per cent.

It is of interest to add that the number in the first year of the course for the Higher National Certificate is 422 in the current session, an increase of 68 per cent over the corresponding figure two years ago.

Even greater proportionate increases are shown by the numbers of students taking part-time courses leading to the Institute's Graduateship examination, details of which are given in table 7. Most of these students are holders of the Higher National Certificate in Applied Physics, although some of them will be holders of the London General degree at pass standard who are also required to take part of the Graduateship examination before being eligible for membership of the Institute. The total has almost trebled in two years.

Table 7.—*Students for Graduateship Examination*

	1955-6	*1956-7*	*1957-8*
C.A.T.	16	37	48
London	15	20	19
Other Colleges	17	37	66
Total	48	94	133

Diploma Courses

An interesting development has been the establishment of full-time or sandwich courses leading to diplomas, especially those for the new Diploma in Technology awarded by the National Council for Technological Awards. The Institute of Physics has welcomed this new development and, indeed, has for some years urged the need for courses of this kind. Table 8 gives the numbers of students in each of the years of those courses which are recognized by the Institute. Successful students in all these courses will be given complete exemption from the Institute's academic requirements for membership. The courses include all except one of those so far recognized by the National Council for Technological Awards.

Table 8.—*Students (1957-8 session) in full-time or sandwich courses leading to Diplomas recognized by the Institute*

	1st Year	*2nd Year*	*3rd Year*	*4th Year*
C.A.T.	40	34	14	—
London	27	13	6	—
Other Colleges	30	24	8	7
Total	97	71	28	7

Table 6.—*National Certificates in Applied Physics—final year candidates*

	Ordinary Cert. Candidates			*Higher Cert. Candidates*		
	1955-6	*1956-7*	*1957-8*	*1955-6*	*1956-7*	*1957-8*
C.A.T.	90	104	107	55	52	63
London	67	87	57	36	39	45
Other Colleges	279	385	484	64	97	141
Total	436	576	647	155	188	249

The single course recognized by the National Council but which the Institute has refused to accept has at present 15 students in the first year. None of the physics courses for the Diploma in Technology is yet beyond the third year; the seven students in a fourth-year course are at the Royal College of Science and Technology, Glasgow, studying for the College Associateship which is recognized by the Institute.

APPENDIX I

UNIVERSITIES FROM WHICH DATA HAVE BEEN RECEIVED

Birmingham
Bristol
Cambridge
Durham :
  Durham Colleges
  King's College, Newcastle upon Tyne
Exeter
Hull
Liverpool
Leeds
London :
  Birkbeck College
  Imperial College
  King's College
  Queen Mary College
  Royal Holloway College
  University College
Manchester :
  Faculty of Science
  Faculty of Technology
Oxford
Nottingham
Reading
Sheffield
Southampton
University College of North Staffordshire
Aberdeen
Edinburgh
Glasgow
St. Andrews :
  Queen's College, Dundee
Wales :
  University College of Wales, Aberystwyth
  University College of North Wales, Bangor
  University College of South Wales and Monmouthshire, Cardiff
  University College of Swansea
Belfast

APPENDIX II

TECHNICAL COLLEGES SUPPLYING DATA

(*a*) *Colleges recognized by the Institute for the purpose of its Membership regulations :*

Aberdeen, Robert Gordon's Technical College
Birmingham College of Technology
Blackburn Technical College
Bolton Technical College
Bournemouth Municipal College of Technology and Commerce
Bradford Institute of Technology
Brighton Technical College
Bristol, College of Technology
Cardiff, Welsh College of Advanced Technology
Chatham, Medway College of Technology
Chelmsford, Mid-Essex Technical College
Croydon Technical College
Crumlin, Technical College of Monmouthshire
Dagenham, South-East Essex Technical College
Derby and District College of Technology
Edinburgh, Heriot-Watt College
Ewell County Technical College
Glasgow, Royal College of Science and Technology
Gloucester Technical College
Guildford Technical College
Huddersfield Technical College
Kingston Technical College
Leicester College of Technology and Commerce
Letchworth, North Herts Technical College
Liverpool, City of Liverpool College of Technology
London :
  Brunel College of Technology and Acton Technical College
  Battersea College of Technology
  Borough Polytechnic
  Chelsea College of Science and Technology
  Northampton College of Advanced Technology
  Northern Polytechnic
  The Polytechnic, Regent Street

Sir John Cass College
South-East London Technical College
West Ham College of Technology
Woolwich Polytechnic
Loughborough College of Technology
Norwood Technical College
Nottingham and District Technical College
Oxford, College of Technology, Art and Commerce
Paisley Technical College
Portsmouth College of Technology
Preston, Harris College of Further Education
Reading Technical College
Rotherham College of Technology
Rugby College of Technology and Arts
Salford, Royal Technical College
Southend-on-Sea Municipal College
Stoke-on-Trent, North Staffordshire Technical College
Sunderland Technical College
Swansea Technical College
Treforest, Glamorgan Technical College
Walthamstow, South-West Essex Technical College
Wigan and District Mining and Technical College
Wolverhampton and Staffordshire College of Technology

(*b*) *Colleges not recognized for the purpose of the Membership regulations, but offering courses for the Ordinary National Certificate in Applied Physics :*

Bedford, The Mander College
Cambridge, Cambridgeshire Technical College and School of Art

News of Members

FELLOWS

K. Deutsch has been appointed Research Lecturer in the Department of Zoology at the University of Edinburgh.

K. S. G. Doss is now Director of the Central Electro-Chemical Research Institute of Alagappa College, Remand District, India.

E. George has been appointed Principal of Wellingborough Technical College, Northants, as from September 1.

M. E. Haine is now Manager of the Research Laboratory of Siemens Edison Swan Ltd., Harlow, Essex.

A. K. Head has recently joined the C.S.I.R.O. Division of Tribophysics, the University, Melbourne, Australia.

R. F. Hanstock has joined the staff of the United Kingdom Atomic Energy Authority Industrial Group at the Research and Development Branch, Culcheath, Warrington, Lancs.

W. Railston has been seconded as Scientific Adviser to the Commonwealth Relations Office, with special responsibility for scientific problems of the Colombo Plan.

L. Rotherham has been appointed a full-time member of the Electricity Generating Board.

R. Schnurmann has taken up an appointment with Esso Research Ltd., Abingdon, Berks, as a Research Associate.

P. Vigoureux is now working at the National Physical Laboratory, Teddington, Middx.

ASSOCIATES

M. Bridger has recently been appointed Head of the Department of Mathematics of Leicester College of Technology and Commerce.

J. G. Butlin has joined the staff of the British Boot, Shoe and Allied Trades Research Association, Kettering, Northants, as a Development Physicist.

P. Chippendale has been appointed Lecturer in Physics at the Royal Technical College, Salford, Lancs.

P. M. Cook is now Research Manager with J. J. Habershon & Sons Ltd., Rotherham, Yorks.

J. S. Courtney-Pratt is with Bell Telephone Laboratories, New Jersey, U.S.A.

T. C. Common was recently appointed to a Lectureship in Physics at the E.M.I. College of Electronics, London.

J. Hart has joined the staff of Carleton University, Ottawa, Canada, as Associate Professor of Physics.

C. A. Hogarth is Head of the Physics Department of Brunel College of Technology, Acton.

E. S. Hotston recently took up an appointment with the United Kingdom Atomic Energy Research Establishment at Harwell, Berks, as a Senior Scientific Officer.

W. F. Kilby is now working in the Textile Research Laboratory of Courtaulds Ltd., Braintree, Essex.

G. G. Miller is employed as a Research Physicist by the British Rayon Research Association at the Heald Green Laboratories, Manchester.

J. Nightingale has recently joined the staff of the Royal Technical College, Salford, Lancs, as a Lecturer in the Department of Pure and Applied Physics.

M. Possener is a physicist with Semiconductors Ltd., Swindon, Wilts.

L. G. Penhale is a Senior Lecturer in Physics at The Royal Military College of Science at Shrivenham, Wilts.

B. W. Purslow is now a Senior Scientific Officer with the Army Operational Research Group at West Byfleet, Surrey.

B. Samways has recently been appointed Technical Director, Colodense Ltd., Bristol.

D. R. Scott has taken up an appointment as Senior Lecturer in the Department of Mining at The Royal College of Science and Technology, Glasgow.

G. Selwood has joined Wilmot Breeden Ltd., Bridgwater, Somerset, as Chief Engineer.

R. V. Tamhankar is working at the Institut de Recherches de la Sidérurgie, France.

A. W. S. Tarrant is taking up a post as Lecturer in Spectroscopy at the Battersea College of Technology, London.

D. P. C. Thackeray is with Vickers Group Research Establishment, Weybridge, Surrey.

A. H. Ward has been appointed Senior Lecturer in the Department of Physics of the University College of Ghana.

W. M. Williams has recently joined the staff of the Department of Metallurgical Engineering of the University of Toronto, Canada.

P. W. Wright is now at the United Kingdom Atomic Energy Authority's Atomic Weapons Research Establishment, Aldermaston, Berks., as a Senior Scientific Officer.

D. J. C. Yates is employed as a Research Associate in the School of Mines of Columbia University, U.S.A.

GRADUATES

F. Davey is now teaching at Todmorden Grammar School, Yorks.

G. T. Downing has recently taken a post as Assistant Lecturer in Physics at The North Gloucester Technical College, Cheltenham.

G. Ellington is now with Canadair Ltd., Montreal, in their Special Weapons Engineering Division.

J. S. Hatton is employed as a Laboratory Engineer with The General Electric Co. Ltd., at their Telephone Works, Coventry, Warwicks.

D. J. Hayes has joined the staff of the United Kingdom Atomic Energy Authority Industrial Group at the Research & Development Branch of the Springfields Works, Nr. Preston, Lancs.

P. Humphreys is now employed as an Engineer in the Optical Systems Section of the Navigation Research Group of A. V. Roe & Co. Ltd., at Chertsey, Surrey.

G. A. Luck has taken a position with The General Electric Co. Ltd., at the Fraser Chalmers Engineering Works, Erith, Kent.

A. J. M. MacLeod is employed at Marconi's Wireless Telegraph Co. Ltd., Great Baddow, Essex.

J. E. S. MacLeöd is at the Royal College of Science and Technology, Glasgow, in the Department of Natural Philosophy.

D. May has joined the staff of Glass Yarns and Deeside Fabrics Ltd., Camberley, Surrey.

G. Mills is now teaching Science at St. Augustine's Secondary School, Glasgow.

J. G. Moore is employed by The Fairey Aviation Co. Ltd., Hayes, Middx. as an Assistant Physicist.

G. Rowlance has recently joined the Reactor Division of the United Kingdom Atomic Energy Authority Research Establishment at Harwell, Berks.

D. Rowan has been appointed Senior Physicist in the Department of Physics of the Western Regional Hospital Board, Glasgow.

T. G. R. Rawlins is working as a Research Physicist at the Northern Electric Co. Ltd., Montreal, Canada.

M. H. Saunders has joined the staff of the British Thomson-Houston Co. Ltd., Rugby, Warwicks, in the Research Department.

R. W. Snell is a Lecturer in Petroleum Production Engineering at the University, Birmingham.

R. C. Stanley is employed as a Physicist by the Central Electricity Authority Research Laboratories, Leatherhead, Surrey.

P. P. Starling is now working as a Spectrographer at Applied Research Laboratories (Europe) Ltd., Lausanne, Switzerland.

D. Strike has recently been appointed an Assistant Lecturer in Physics at the Technical College of Monmouthshire, Crumlin, Mon.

P. M. Tyler has taken a post as a Magnet Technician at Darwins Ltd., Sheffield.

A. Wright is now at the Radio Research Substation of the University of Malaya.

Branch and Group News

Education Group and South-Western Branch Conference

A Joint Conference between the Education Group and the recently formed South-Western Branch was held on Wednesday, Thursday and Friday, April 9, 10 and 11, 1958, in the University of Bristol. The subject of the Conference was "Physics in Schools," and there was an attendance of over a hundred members. These came chiefly from schools, colleges and universities in the south and south-west of England, but some came from further afield, and from research departments, education authorities and industry.

Owing to the absence of the Vice-Chancellor of the University abroad in Cyprus, the Conference was opened by Professor A. M. Tyndall, the first Professor of Physics in the University of Bristol. He considered the overloading of the physics syllabus due to the increasing flow of new knowledge, and the problem of what could be left out of a syllabus. He recounted how Sir William Bragg had advocated the dropping of acoustics, but later found himself towards the end of the First World War, the chairman of a committee on the application of acoustics to the detection of submarines. Then he had to complain that very few people knew anything about acoustics.

Mr. A. D. C. Petersen, Director of the Department of Education, Oxford, and formerly Headmaster of Dover College, was the first speaker, on "General Education and Physics in the Sixth Form." He had never had a formal physics lesson, but he had observed much physics teaching. He firmly believed that the main object in the teaching of sixth-formers was to arouse their curiosity and interest, and get them to ask the right questions. General education should be the function of the schools; the purpose of secondary education should be (*a*) to impart skills and knowledge, (*b*) to train the mind of the pupil, and (*c*) to encourage happy and stimulating activities. He was against early specialization and the emphasis on the acquisition of knowledge, and in favour of redressing the balance in the education of physicists by having 40 per cent of time devoted to general education subjects, or by the wider spread of special studies. Teaching less physics to physicists might handicap them in competing for entry to the science faculties of the universities whose standards he regarded as being higher than necessary. The subject could be broadened by the introduction of the history and philosophy of science.

(L. to R.)—Miss E. E. Higgins, Dr. N. Thompson, Mr. G. W. Warren, Mrs. C. E. Arregger and Dr. R. W. France.

Mr. N. Clarke (left), Dr. J. Topping and a visitor.

The Conference members attended a Conference Dinner in Wills Hall and later saw two films produced by Encyclopaedia Britannica Inc., from their series designed to give instruction in science in schools where there is no science teacher as occurs in parts of America. One film was a lecture film about Heat, and this was illustrated by geysers and refrigerators which could be expected to arouse the interest of the American pupil. The other film was an experiment film and gave full details of the experiment performed by the teacher in the film on the determination of the acceleration due to gravity by means of a freely falling body.

A discussion followed on the use of these films in particular, and on the use of film, radio and television in general.

On Thursday morning, D. W. Scott, Lecturer in the Department of Education, University of Bristol, spoke about "Some Problems in Physics Teaching in Middle and Upper Forms of Grammar Schools." Among the problems that he considered were, the small portion of time devoted to physics, the space and equipment available, the correlation with the mathematics teaching and the need for the right kind of mathematics for physicists which should include the teaching of approximations. He dealt with the common ground between physics and chemistry in the sixth form, such as radioactivity and electrolysis. He made a plea for more films suitable for the teaching of physics, and concluded that the object of teaching physics was to impart an understanding of the universe and to encourage the boy to work and think for himself.

In opening the subsequent discussion, Mr. Nightingale, spoke about the problems of the overlarge sixth form, apparatus difficulties and how they could be overcome by improvisation and apparatus pools, about the training of laboratory assistants, the design of laboratories and liaison with architects. Other speakers enlarged upon these points.

In the second half of the morning session, Mrs. C. E. Arregger, Hilger and Watts, Ltd., gave a talk on "The Recruitment of Women as Physicists—the Problem in the Schools." She described how the bias against women doing anything of a scientific nature started from a very early age by the selection of toys and hobbies, thereby preventing girls acquiring skill in the use of tools. Also the girl was expected to help in the home. A further bias against girls was the timetable in schools, for even in co-educational schools, girls did less science than the boys. It was stated that headmistresses and parents were in general ignorant of the facilities available for training in the technical colleges and of the careers available to women scientists. The reluctance of employers to advertise for and to engage women, and of university departments to accept women was also stated. The effect on recruitment by the visits of old students to the schools was pointed out.

Miss E. E. Higgins, The Girls' High School, Gloucester, opened the discussion by stating that we must satisfy girls and their parents that physics is a worthwhile career. She suggested that girls preferred a job which involved contact with people, and that the popularity of the medical services was in part due to this preference. She wondered whether the demand by industry for women was a temporary or a permanent one. Mr. H. L. Walker gave some of his experiences as a teacher of the sixth form of a girls' school. He considered that the lack of mathematical equipment was the main cause of the loss of interest in physics by a girl. Mr. R. R. Dale gave some of the reasons why girls were less well equipped in mathematics than boys. Mother St. Joan of Arc thought that it was the attitude of the teacher that affected the popularity of mathematics. Professor F. A. Vick gave some of his experiences in the teaching of Arts women and suggested better teaching methods to overcome the bogy. Mr. T. G. Jones emphasized the importance of pre-school training. Professor G. K. T. Conn stated that there was no resistance in the universities to women physicists. Dr. N. Thompson stated that the University of Bristol gave preference to women, even though they did not do as well as men. He agreed that women preferred occupations that involved people.

The afternoon session was opened by Mr. W. Llowarch, University of London Institute of Education, with a lecture on "The role of Practical Work in the Education of a Physicist." He deplored the treatment of practical work as a separate branch taught mainly for examination requirements. He considered that it had a vital part to play and regretted that a true experimental approach was generally lacking. He emphasized that physics was a practical subject and should be taught practically. He considered the two divisions of practical work, (*a*) demonstration, the object of which was to stimulate interest and wonder, to give enlightenment and experiment, and (*b*) laboratory, to teach techniques, to give experience and experiment. Other topics considered were practical examinations, pupils' reactions, types and experience of teachers and the correlation with theory.

The discussion which followed dealt with instruction cards, practical books, practical examinations and records and their assessment by examination boards.

After tea, Professor C. H. Dobinson, Department of Education, University of Reading, presented a paper on "Science Examinations at 'O' and 'A' level for future Physicists." Supported by statistical evidence, the reports of other conferences, the Policy Statement of the Science Masters' Association and by the lecture given by Mr. Peterson, Professor Dobinson made a strong plea for a broad foundation in the fundamentals of science and for the continuation of mathematics suitable for scientists, throughout the whole of

school life. He considered the teaching of science and arithmetic in the primary school, the fact that the choice of specialized subjects started at 13 years, and that this should not be necessary until the sixth form was reached. Ways of improving the teaching of mathematics, especially to girls, were dealt with. The purposes and content of the "A" level examination was considered, and methods by which it could be improved were suggested. Professor Dobinson urged that this conference should be followed up and its conclusions supplemented. He was also in favour of wider representation to include headmistresses and local authorities.

Dr. Thompson opened the discussion by asking for a common curriculum in general science for all pupils up to " O " level, and that the status of the " O " and "A" level examinations should be considered in the light of the various purposes that they are made to serve. Other speakers made further suggestions with reference to the character and scope of "A" level examinations. Professor Dobinson in summing up supported the principle that two or three subjects should be taken by the same teacher and that examination boards should experiment more.

On Friday morning Professor G. K. T. Conn, University of Exeter, spoke about "The Transition from School to University " and referred to the difficulty of the young inexperienced first year student who had come direct from school, and how the first year required the leavening of more mature students who had come from industry or national service. He dealt with the administrative problem of pressure for places, and multiple applications. The lack of professional responsibility was deplored. Figures were given about the numbers of university entrants, and a plea made for students to be free to choose their university and for the universities to choose their students. The problem facing the first year student in coming to terms with himself, and the different attitude of the university to physics were outlined.

Dr. J. Topping, Principal of Brunel College of Technology, followed with a paper on " The Education of Physicists in Technical Colleges." He gave a clear and precise picture of the work technical colleges had done, and how the 1956 White Paper on Technological Education had transformed technical education. He explained how the National Council for Technological Awards had introduced the Diploma in Technology, which was to be equivalent to, but different in purpose from, an honours degree of a British University. The organization of sandwich courses was described, and the problems outlined. The ways in which the Diploma in Technology course differed from the honours degree course were outlined. Dr. Topping closed with an expression of justifiable hope that our Colleges of Technology would soon compare favourably with the American and Continental Institutes of Technology.

The final discussion was opened by Mr. R. R. Dale, Department of Education, University College of Swansea. He considered the methods of selection of entrants to university, the granting of scholarships, the abrupt transition to university and the large number of failures at the end of the first year. He considered that the obstacles to improvement were within the universities themselves, and he was critical of the marking of the entrance examinations by the university staff. He recommended inclusion in the examination of an objective test consisting of a large number of questions which could be quickly marked right or wrong, together with verbal intelligence and vocabulary tests.

In the afternoon a party of Conference members were conducted round the Physics Laboratory.

The University of Bristol, the Physics Department, and especially Dr. N. Thompson were warmly thanked for their hospitality and for the enormous amount of work that had been done to ensure the undoubted success of the Conference.

T. H. TYLER.

Several of the principal contributions to this conference will be published in full in the BULLETIN

The Register

ELECTIONS TO MEMBERSHIP

THE FOLLOWING ELECTIONS WERE MADE BY THE BOARD ON MAY 6, 1958

An asterisk (*) indicates transfer from another grade

FELLOWS

Adam, Hermann, Ph.D., Head of Department, Lancashire Dynamo Nevelin Ltd., Heald Green.

*Archard, John Frederick, B.Sc., Ph.D., Research Physicist, Associated Electrical Industries Ltd., Aldermaston, Berks.

*Benbow, John Jones, M.Sc., Technical Officer, Imperial Chemical Industries Ltd., Northwich, Cheshire.

*Bluhm, Max Michael, B.Sc., Ph.D., Principal Hospital Physicist, Western Regional Hospital Board, Glasgow.

*Crook, Alfred William, B.Sc., Ph.D., Sub-Section Leader, Associated Electrical Industries Ltd., Aldermaston, Berks.

*Darbyshire, Jack, M.Sc., Principal Scientific Officer, Royal Naval Scientific Service, Godalming, Surrey.

Elton, Lewis Richard Benjamin, B.A., B.Sc., Ph.D., Head of Physics Department, Battersea College of Technology, London.

*Jaffe, Joseph Henry, B.Sc., Ph.D., Senior Scientist, Weizman Institute of Science, Rehovoth, Israel.

*Kellerman, Ernst Walter, Ph.D., Lecturer, University of Leeds.

*Litting, Colm Norbert Weisman, B.Sc., Ph.D., Lecturer, University of Manchester.

*McGill, Donald, M.Sc., Senior Physics Master, Glasgow Academy.

*Steward, Edward George, B.Sc., Ph.D., Senior Scientist, The General Electric Co. Ltd., Wembley, Middlesex.

Stroh, Alan Neil, M.Sc., Ph.D., Lecturer, University of Sheffield.

ASSOCIATES

*Adams, Henry Stewart, B.Sc., Research Engineer, G. & J. Weir Ltd., Cathcart, Glasgow.

*Ames, Gerald James, B.Sc., Group Leader, The General Electric Co. Ltd., Stanmore, Middlesex.

Andrews, Matthew Ian, B.Sc., Lecturer, Paisley Technical College.

Angus, Ronald George, M.A., Lecturer, Robert Gordon's Technical College, Aberdeen.

Baldwin, Dennis George, B.Sc., Research Physicist, Shell Research Ltd., Chester.

Barber, Barry, M.A., Assistant Physicist, The London Hospital.

*Calder, David Alexander, B.Sc., Assistant Lecturer, North Staffordshire Technical College, Stoke-on-Trent.

Carruthers, John Alastair, B.Sc., D.Phil., Research Fellow (D.S.I.R.), The Clarendon Laboratory, Oxford.

*Clark, Laurence George Stanley, B.Sc., Scientific Staff, The General Electric Co. Ltd., Stanmore, Middlesex.

*Cloud, Peter Ronald, B.Sc., Senior Staff Member, General Precision Laboratory, New York, U.S.A.

Easlea, John Keith, M.Sc., Physics Master, Palmer's School, Grays, Essex.

Haynes, Robert Hall, B.Sc., Ph.D., Department of Physics, St. Bartholomew's Hospital, London.

Holloway, Dennis Glyn, B.Sc., Ph.D., Lecturer, University College of North Staffordshire, Keele, Staffs.

McGeachin, Hugh McDougall, B.Sc., Ph.D., Physicist, Albright & Wilson (Manufacturing) Ltd., Oldbury, Birmingham.

*Morton, David Henry, M.A., Research Physicist, Courtaulds Ltd., Droylsden, Lancs.

Rouse, Albert Peter, B.Sc., Assistant Physics Master, Haberdashers' Aske's Hampstead School, London.

*Seal, Michael, M.A., Ph.D., Research Physicist, University of Cambridge.

*Singleton, Donald George, M.Sc., Lecturer, University of Queensland.

*Smith, Michael John, B.Sc., A.R.C.S., Research Physicist, Electric and Musical Industries Ltd., Hayes, Middlesex.

*Symes, William Sydney, B.Sc., Technical Officer, British Nylon Spinners Ltd., Pontypool, Mon.

Thorburn, Robert, B.Sc., Ph.D., Lecturer, Birkenhead Technical College, Cheshire.

*Tibbetts, Derek Ross, B.Sc., A.R.C.S., Engineer, Standard Telecommunication Laboratories Ltd., Enfield, Middlesex.

*Truelove, Antony Harry, M.A., Engineer, Standard Telecommunication Laboratories Ltd., Enfield, Middlesex.

Turner, Clara, D.Sc., Scientific Officer, British Insulated Callenders' Cables Ltd., London.

Ward, Clifford Herbert, M.Sc., Advanced Physics Master, Chichester High School for Boys.

West, Roger, M.A., Technical Manager, United Insulator Co. Ltd., Chessington, Surrey.

Whitworth, Robert William, M.A., Ph.D., Research Fellow, University of Birmingham.

GRADUATES

Archenhold, Wolfgang Freidrich, B.Sc., Graduate Apprentice, The English Electric Co. Ltd., Nelson Research Laboratories, Stafford.

Barlow, Brian Charles, B.Sc., Geophysicist, Bureau of Mineral Resources, Melbourne.

Carruthers, Derek Dennison, B.Sc., Research Student, University of Durham, King's College, Newcastle upon Tyne.

*Choong, Kui Lam, B.Sc., University of Malaya.

Daisley, Roy Edward, B.A., Technical Engineer, Bristol Aero-Engines Ltd., Filton, Bristol.

*Davies, Keith Frederick, B.A., Aerodynamicist, Blackburn and General Aircraft, Brough, Yorks.

*Evans, William Alan, B.Sc., University of Birmingham.

*Gay, Lionel Stanley, B.Sc., Research Student, University of Natal, South Africa.

Hall, Ralph Martin Sykes, M.A., Physical Chemist, Central Electricity Authority, Leatherhead, Surrey.

Higgins, John Christopher, M.A., Assistant Lecturer, Northern Polytechnic, London.

Hughes, John Alan, B.Sc., Electronic Engineer, British Thomson-Houston Co. Ltd., Rugby.

Hughes, Kenneth John, B.Sc., Imperial Tobacco Co. Ltd., Bristol.

Jones, David Alfred, B.Sc., Research Student, University of Bristol.

Jones, Ierun Rinallt, Research Student, University College of Wales, Aberystwyth.

*Kail, John Alan Elliott, B.Sc., Research Student, Queen Mary College, London.

Leaf, Geoffrey Glanville, B.Sc., Graduate Apprentice, The English Electric Co. Ltd., Nelson Research Laboratories, Stafford.

*Lim, Chuan Poh, B.Sc., Research Student, University of Malaya.

*Lim, Tan Seng, B.Sc., Senior Science Master, High School, Bukit Mertajam, Malaya.

Loggie, Ronald George Cran, Scientific Officer, U.K. Atomic Energy Authority, Dounreay.

Mawdsley, Peter, B.Sc., U.K. Atomic Energy Authority, Aldermaston, Berkshire.

Melling, Evelyn Rose, B.Sc., Dunlop Research Centre, Erdington, Birmingham.

Novice, Michael Alfred, M.Sc., Research/Development Physicist, English Electric Valve Co. Ltd., Chelmsford, Essex.

Overy, John, B.Sc., Mathematician-Physicist, The Plessey Co. Ltd., Ilford, Essex.

Park, Albert Barrymore, B.Sc., Engineer, E.M.I. Electronics Ltd., Hayes, Middlesex.

Penn, Alan William, B.Sc., Research Physicist, Associated Electrical Industries Ltd., Aldermaston, Berkshire.

Rhead, Gordon Edward, B.Sc., Demonstrator, Manchester College of Science and Technology.

Roberts, William Kenneth, B.Sc., Senior Scientific Officer, British Leather Manufacturers' Research Association, Egham, Surrey.

Scammell, Kenneth Tom, Senior Physics Master, Badingham College, Leatherhead, Surrey.

Shelton, Michael Joseph Barry, Junior Dynamics Engineer, Sir W. G. Armstrong Whitworth Aircraft Ltd., Whitley, Coventry.

Shipley, Joan, B.A., Laboratory Technician, Hilger & Watts Ltd., London.

*Silcox, John, B.Sc., Research Student, University of Cambridge.

Spurlock, Kenneth Ernest, B.Sc., Executive Engineer, General Post Office, Wales and Border Counties.

Starr, Christopher John Rolph, B.Sc., University of Southampton.

Steel, George Gordon, B.Sc., Research Student, Institute of Cancer Research, Belmont, Surrey.

Sturman, Hugh Gregory, Technical Assistant, U.K. Atomic Energy Authority, Sellafield, Cumberland.

One hundred and two Students and five Subscribers were also elected

The Institute's Journals

PRINCIPAL CONTENTS OF THE JUNE, 1958, ISSUES

Journal of Scientific Instruments: Volume 35, No. 6

SPECIAL ARTICLE

The Physical Society's Exhibition—London, 1958. By A. J. Philpot, C.B.E., F.Inst.P.

A general survey is given of the newer developments of instruments and apparatus exhibited.

ORIGINAL CONTRIBUTIONS

A cathode-ray tube analogue-to-serial digital converter. By J. Willis and M. G. Hartley.

Small fluctuations of the screen equilibrium potential of a cathode-ray tube cause proportionate small fluctuations in the steady secondary emission current arriving at a collector anode. The application of this fluctuation of secondary emission to an analogue-to-serial digital converter is discussed. An investigation of the parameters affecting changes of secondary emission using an electrode on the face of the tube, maintained at an alternating potential, to vary the screen potential is described. The secondary emission is observed as a signal, developed across a resistor between collector and earth, at screen electrode supply frequency, amplitude-modulated by the changes in secondary emission which occur when the screen is scanned by an electron beam.
The effects of electrode potential, electrode width, steady state collected current, beam focus, bias applied to the collector and accelerating voltage are examined. The results are compared with those predicted from electrolytic tank studies. The variation of output over the screen surface under different operating conditions is discussed. Experiments to determine minimum electrode width and spacing, consistent with the production of a discrete pulse output from each electrode of a pattern, are described.

An ultra-micro flame spectrophotometer. By D. Exley and D. Sproat.

A description is given of a modified Beckman DU flame spectrophotometer fitted with an integrating circuit. An electronic switching arrangement is incorporated which enables accurate integration from small volumes of liquid. It is 1,000 times more sensitive than the original Beckman instrument. Burning the samples dissolved in acetone increases the sensitivity to 60,000 times, when 3×10^{-13} g of sodium and 10^{-10} g of magnesium can be detected; 1–10 μg amounts of the latter element in biological fluids have been estimated. The instrument can be used as a direct-recording device without integration. Switching arrangements enable it to be used as the original Beckman DU spectrophotometer both for absorptiometry and flame photometry.

The emission of light from electric discharges of microsecond durations in gases at atmospheric pressure. By D. P. C. Thackeray, A.Inst.P.

This paper compares the performance of four types of spark discharge, widely used as light sources of high intensity and short duration. Using the same capacitor and stored energy, electrical and light emission wave forms, and integrated spectra, were recorded for each type of discharge. Air sparks, both free and guided across the surface of an insulator, and argon sparks both within a jet of argon, and enclosed by a quartz capillary tube, were studied in this manner. The results are discussed in terms of the possible applications in fast photography and the photo-irradiation of materials. Particular attention is drawn to the novel properties of the discharge within an argon jet, as this affords a source of high positional stability and repeatability of performance, while retaining the high intensity and small size of other discharges.

A design for a multi-channel infra-red spectrometer using transistor electronics. By D. G. Avery, A.Inst.P., and R. C. Bowes.

This paper describes a simple spectrometer in which a number of indium antimonide photoconductive cells are placed in the plane of the spectrum, each acting as its own "exit slit" and receiving light of different wavelengths. The output from each can be handled separately, or they can be coupled to record the difference in intensity at two wavelengths. A large number of ways of using these outputs are feasible and the instrument described was constructed to demonstrate the principles, rather than to solve any particular problem.

A sensitive micrometer for measuring small displacements. By J. Norbury, F.Inst.P., and D. Shewring, Grad.Inst.P.

A variable parallel plate capacitor associated with an oscillating circuit forms the basis of an apparatus which can measure small displacements of the order of 200Å. The apparatus is so designed as to combine robustness with sensitivity, ease of calibration and reproducibility. The use of a diode pump integrator circuit makes the sensitivity independent of the gain of the a.c. amplifier. The capacitor is of simple construction and standard electronic components are used throughout.

Leak testing of vacuum plant by helium analysis. By E. Glueckauf and G. P. Kitt.

An apparatus is described for determining the extent and location of leakages in the operation of gas plants, working at reduced pressures, by the analysis of the rare gases, helium and neon, contained naturally in the inleaking air. It can generally be applied when hydrogen, helium and neon are normally absent from the plant gases. An accuracy of 0·5% for the analysis of a sample of gas containing 0·5 ml. of leakage air can be obtained, but it appears that the detection of 0·01 ml. of air is the lower limit using a commercial ionization gauge as the sensitive element.

British Journal of Applied Physics: Volume 9, No. 6

SPECIAL ARTICLE

Photoconductivity*. By D. A. Wright, F.Inst.P. The basic factors influencing photoconductivity are first discussed, and the general pattern of behaviour to be expected is indicated. The preparation and properties of cadmium sulphide are then dealt with in some detail. Other photoconducting compounds are described more briefly, and it is shown that their properties also fit into the general pattern. Following a discussion of the nature of the impurities and defects in the crystal lattice which influence the sensitivity, the applications of photoconductors are outlined briefly.

* This article is based on a talk given to the Electronics Group of The Institute of Physics in October, 1956.

ORIGINAL CONTRIBUTIONS

Sources of error in electron stereomicroscopy. By R. I. Garrod, F.Inst.P., and J. F. Nankivell, A.Inst.P.

A theoretical examination is made of the use of the stereoscopic technique for the determination of vertical elevations in electron microscope specimens. It is shown that the variation in optical object distance due to tilting the specimen may introduce serious errors even for object points close to the optic axis of the microscope. Other possible sources of error are also analysed, and it is concluded that in practice, apart from limits due to resolution, these are likely to be of minor importance in relation to the tilt error and the precision attainable in the measurement of parallax. Consideration has been given to possible means of reducing the tilt error : no wholly satisfactory solution has been found, and it is necessary for precision work to maintain the axis of tilt of the specimen close to the optic axis within very narrow limits.

The pneumatic conveying of spheres through straight pipes. By J. A. Hitchcock and C. Jones, A.Inst.P.

This paper reports a technique for the study of pneumatically-conveyed solids. Two equations have been established experimentally which give the pressure gradient and solid velocity along a pipe when non-adhesive spherical particles (up to 7 mm in diameter) are being conveyed with little or no acceleration by an airstream through the pipe. Straight, smooth and horizontal pipes (up to 7 cm in diameter) are considered. Included in the paper is a section examining the practical application of the equations, and a successful check of the equations is made with some values of the variables outside the range studied in the paper.

Mechanical testing of materials in the transition region between steady flow and failure. By A. Jobling, and J. E. Roberts, A.Inst.P.

An attempt has been made to overcome some of the defects of the standard methods of mechanical testing of materials. The new method, in which the deformation is brought about by attaching the specimen to a substrate, shows that when the final mechanical failure occurs, continuity is preceded by a region of disturbed flow in which the flow lines appear as a pattern of remarkable regularity, the direction of which is not that of maximum shear.
Materials such as dry powders, pastes, polymers and vacuum-deposited metals have been studied and show unexpected common features, e.g. fatigue and relaxation of work hardening by vibrations.

The time-constant of carbon composition resistors. By G. H. Rayner.

The inductance and capacitance of small composition resistors have been determined. It is shown that the time-constant can be obtained with high accuracy and that for a common type it does not exceed 1×10^{-9} H/Ω in magnitude for resistance values between 10Ω and 1 kΩ and it is very close to zero for a value of 100 Ω.

Bonding optical components to metal mounts. By K. H. Spring.

Various methods of bonding optical components to metal mounts, using synthetic resin adhesives, are described. In some cases a rubber interlayer is necessary to maintain resilience and prevent strain in the glass. A sandwich-type silicone rubber interlayer may be used to maintain resilience at temperature extremes. The tensile strength and shock resistance of the various types of bond are discussed, and a laboratory shock-tester suitable for small specimens is described.

The effective coefficient of friction for strings traversing cylinders transversely and slantwise. By C. Mack, F.Inst.P., and C. Rubenstein, A.Inst.P.

A formula is given for the effective coefficient of friction in terms of the constants of the power law of friction, the angle of wrap, and the on-going tension, for strings traversing cylinders transversely or slantwise. A table, which enables this coefficient of friction to be computed quickly and simply, is also given. Some experimental evidence for the accuracy of the formula for the slantwise case is described, while references to the experimental evidence in the transverse case are given.

A " super-elastic " single crystal calibration bar. By W. A. Rachinger.

Elastic strains of up to 4% can be obtained in a copper-aluminium-nickel alloy in the form of a single crystal suitably heat treated. The high elasticity is due to a reversible martensite transformation induced by stressing. The methods of production and heat treatment of large crystals are described together with details of mechanical properties. The alloy can be machined by conventional methods. Suggestions are made for the development of other super-elastic alloys.

COMMONWEALTH OF AUSTRALIA

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

IRRIGATION RESEARCH STATION

Appointment No. 500/95 of Design Engineer or Physicist

Applications are invited for appointment to a position of Engineer or Physicist with the Organization's Irrigation Research Station, located at Griffith, New South Wales. Work at this Station is concerned chiefly with investigations into the many phases of horticultural and agricultural production under irrigation in the Murrumbidgee Irrigation Areas of New South Wales. The fields of research include soils, hydrology, plant physiology and plant nutrition. The appointee will be required to link the design of equipment and apparatus to the needs of the physicist and plant physiologist. He should be an experienced engineer, capable of designing a wide range of machines embracing field machinery used for drainage and spray equipment and have a familiarity with electronics which enables a balanced view to be taken between mechanical, hydraulic and electronic methods.

The person to fulfil this post should have to his credit the solution of mechanical problems which may well involve an electronic solution. He should also be associated with some aspect of farming in order to understand the peculiarities of those aspects which are variable and for which no one solution necessarily applies.

The talents required of such a person are that he should not only be a good scientist but should be sufficiently practical in his approach to be able to put the ideas into concrete terms based on good design. He will be expected to take charge of an experimental workshop and be sufficiently wide in his interests to apply his knowledge to the overall engineering problems of irrigation engineering and to develop his own course of investigations.

Applicants should possess a University Honours degree in Engineering or in Science with Physics as a major subject, together with research experience and wide interests in Agricultural Engineering.

Dependent upon qualifications and experience, the appointment will be made within the ranges: Senior Research Officer £A2,048–£A2,323 p.a. or Principal Research Officer £A2,543–£A2,983 p.a. Salary for a female appointee would be £A167 p.a. less than the corresponding male rates quoted.

The appointment will be conditional upon a satisfactory medical examination and appointment carries with it Commonwealth Superannuation Fund or Commonwealth Provident Account privileges.

An appointee migrating from overseas will be eligible for first class sea or air transport to Australia for himself, his wife and family. An appropriate contribution will also be made towards the fares of an Australian appointee, his wife and family, temporarily abroad for study or similar purposes.

Applications quoting Appointment No. 500/95 and stating full name, place, date and year of birth, nationality, marital state, present employment, details of qualifications and experience, and of war service, if any, together with the names of not more than four persons acquainted with the applicant's academic and professional standing, should reach the undersigned from whom further particulars may be obtained, by June 28, 1958.

A. Shavitsky,
Chief Scientific Liaison Officer.

Australian Scientific Liaison Office,
Africa House,
Kingsway,
London, W.C.2.

MIDDLESEX COUNTY COUNCIL

EDUCATION COMMITTEE

BRUNEL COLLEGE OF TECHNOLOGY,
WOODLANDS AVENUE, ACTON, W.3.

Applications are invited for the post of Assistant Grade B in the Department of Physics to teach to the standard of the Diploma of Technology in Applied Physics. There is an opportunity to undertake research.

Salary in accordance with the Burnham (Technical) Report 1956, i.e. £650 × £25–£1,025 plus London allowance and other additions for previous experience as appropriate.

Application forms and further particulars (stamped addressed foolscap envelope) from the Principal to whom completed forms should be returned within 14 days of the appearance of this advertisement.

C. E. Gurr, M.Sc., Ph.D.,
Clerk to the Governing Body.

BRADFORD EDUCATION COMMITTEE
TECHNICAL COLLEGE

Applications are invited for the post of Assistant Grade A in Physics. Candidates should be well-qualified physicists with teaching and/or research and/or industrial experience.

Salary in accordance with the Burnham Technical Award is £475 to £900 per annum, plus additions for teaching and graduate status.

The commencing salary will depend upon qualifications and experience and may be increased up to a maximum of twelve increments in respect of approved service in industry, commerce, or in professional or research work.

Further particulars and application forms may be obtained from the Director of Education, Town Hall, Bradford 1, and completed forms should be returned to the Principal of the College as soon as possible.

A. Spalding,
Director of Education.

CENTRAL ELECTRICITY GENERATING BOARD

PHYSICISTS required at Research Laboratories, Leatherhead, Surrey for research into the non-destructive testing of all types of materials used in the Electricity Supply Industry. The work will consist of developing and applying techniques rather than actual routine testing.

Candidates should have an honours degree or equivalent qualification. Experience in one or more branches of non-destructive testing will be a recommendation, but applicants without experience in this field will be considered.

Salaries within scales £1,055–£1,265 p.a. or £820–£995 p.a.

Applications stating age, qualifications, experience, present position and salary should be forwarded to S. S. Scott, Chief Personnel Officer, 24-30 Holborn, London, E.C.1, by June 30, 1958. Envelopes should be marked " Confidential " quoting ref. PB/127.

BRITISH THOMSON-HOUSTON CO., LTD.

The British Thomson-Houston Co. Ltd., invites applications for posts in its Research Laboratory at Rugby in an expanding research group working on a number of interesting physical problems.

(i) A physicist or physical chemist to carry out experimental work on the relations between gases, ionized gases and solids.

(ii) A mathematician or physicist to carry out mathematical investigations, mainly on problems connected with gas discharges.

Applicants should have good honours degrees, some knowledge of low pressure techniques would be useful but not essential for (i), and some knowledge of digital computer techniques for (ii). The successful applicants will, however, have ample opportunity to acquire and expand their knowledge of these and other techniques. Applicants are invited to write to the Director of Research, The British Thomson-Houston Co. Ltd., Rugby, giving details of age, qualifications, etc., and quoting reference CAM.

ESSEX EDUCATION COMMITTEE

SOUTH-EAST ESSEX TECHNICAL COLLEGE
LONGBRIDGE ROAD, DAGENHAM

Required in September—two assistants Grade B for Physics. Candidates should have an Honours degree in Physics and an interest in some branch of Applied Physics. Teaching and industrial experience is desirable. Salary: £650 × £25 to £1,025 (men) and £580 × £20 to £820 plus equal pay increments (women). Additions to both scales for previous teaching service, approved industrial experience and War/National Service. London allowance (£36 or £48 p.a.) payable.

Details and forms (stamped addressed foolscap envelope) from the Clerk to the Governors at the College.

UNIVERSITY OF BIRMINGHAM

DEPARTMENT OF EXTRA-MURAL STUDIES

Applications are invited for the post of staff tutor in physical science. Applicants should preferably be qualified in physics, but qualifications in any branch of the physical sciences will be considered. The post offers opportunities for experiment in developing science teaching to adult groups and for research in co-operation with Departments of the Faculty of Science. Salary range £900-£1,650 p.a.; initial salary according to qualifications.

Applications (eight copies) together with the names of two referees, should be sent by June 30, 1958, to the Director of Extra-Mural Studies, The University, Edmund Street, Birmingham, 3, from whom further particulars may be obtained.

THE UNIVERSITY OF LEEDS

DEPARTMENT OF PHYSICS

Applications are invited for two appointments in the Department of Physics as either Lecturer or Assistant Lecturer at salaries on the scale £900 × £50–£1,350 × £75–£1,650 a year for a Lecturer, or within range £700–£850 a year for an Assistant Lecturer, according to age, qualifications and experience. Applications (three copies) stating date of birth, qualifications and experience, together with the names of three referees, should reach the Registrar, The University, Leeds, 2 (from whom further particulars may be obtained) not later than June 30, 1958.

BRADFORD INSTITUTE OF TECHNOLOGY

Principal: E. G. Edwards, Ph.D., B.Sc., F.R.I.C.

DEPARTMENT OF PHYSICS

Applications are invited for the post of Assistant Grade B in Physics. Candidates should be well-qualified physicists with teaching and/or research and/or industrial experience.

Salary in accordance with the Burnham Technical Award is £650 to £1,025 per annum, plus additions for training and graduate status.

The commencing salary will depend upon qualifications and experience and may be increased up to a maximum of twelve increments in respect of approved service in industry, commerce, or in professional or research work.

Further particulars and application forms may be obtained from the Principal, Institute of Technology, Bradford, 7.

W. H. Lathem,
Clerk to the Governors.

TECHNICAL ASSISTANTS in the Royal Institution of Great Britain. Vacancies exist for two technical assistants, preferably with National Certificate in Applied Physics as follows:—

(*a*) Assistant in the Lecture Theatre to assist the Senior Experimental Officer in the preparation of experimental demonstrations in all fields of science and in the maintenance and care of equipment.

(*b*) Assistant in the Davy Faraday Research Laboratory, to assist with the construction and maintenance of electronic equipment.

Salary in the range £450–£800 according to age and experience. Day release for further study where appropriate.

Applications to Sir Lawrence Bragg, F.R.S., The Royal Institution, 21 Albemarle Street, London, W.1, by June 28, 1958.

VICTORIA UNIVERSITY OF WELLINGTON

NEW ZEALAND

The council of the Victoria University of Wellington proposes shortly to appoint a Lecturer in the Department of Physics and invites applications from suitably qualified persons for this post. The salary will be £1,025 per annum, rising by annual increments of £50 to £1,275. The initial salary will be determined according to the qualifications and experience of the appointee. An allowance is made towards travelling expenses.

Further particulars and information as to the method of application may be obtained from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1.

The closing date for the receipt of applications, in New Zealand and London, is July 15, 1958.

TECHNICAL MANAGEMENT. Required for training as Assistant to Technical Director—a graduate with broad training in Chemistry, Physics and Mathematics. The post is definitely connected with Works Control, both as regards processes and machines. Applicants must be of a reliant type and capable of taking responsibility in the future.

Apply to Technical Director, Moler Products Ltd., Hythe Works, Colchester, Essex.